

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. <b>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</b>					
1. REPORT DATE (DD-MM-YYYY) 01-05-2011		2. REPORT TYPE Final Technical		3. DATES COVERED (From - To) June 1, 2009 till May 31, 2010	
4. TITLE AND SUBTITLE  (DURIP-09) Near-Field Scanning Optical Microscope/Atomic Force Microscope with Broad-Band Source for Study of Optical Metamaterials and Nanocircuits				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER FA9550-09-1-0448	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)  Nader Engheta, Marija Drndic, Brian Edwards				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  University of Pennsylvania Philadelphia, Pennsylvania 19104				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)  Air Force Office of Scientific Research Suite 325, Room 3112 875 Randolph Street Arlington, VA 22203-1768				10. SPONSOR/MONITOR'S ACRONYM(S)  AFOSR	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-OSR-VA-TR-2012-0908	
12. DISTRIBUTION / AVAILABILITY STATEMENT  Distribution A - Approved for Public Release					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT  With the DURIP Grant Number FA9550-09-1-0448 we purchased a Nanonics MV-4000 Near Field Scanning Optical Microscope (NSOM) and a Fianium SC450-6 Super Continuum laser. Conventional far-field microscopy is limited by the diffraction such that all optical information about features smaller than one-half the wavelength is lost between the sample being investigated and the eye of the observer. This can be likened to the difficulties inherent in trying to understand the layout of an electronic circuit by examining its radio frequency radiation pattern with an antenna from across the room. However, this does not mean that these features do not affect the fields locally. Just as one can understand the local voltages with a voltage probe and oscilloscope, using an NSOM, we can understand the local optical fields using a small aperture on the end of an optical fiber and an avalanche photodiode (APD). While this is a useful description of how an NSOM enables near-field microscopy, the analogy is particularly apropos as our goal is to take the powerful modular nature of conventional electronics and move this into the optical domain using through extreme miniaturization and techniques born out of metamaterials.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT  UU	18. NUMBER OF PAGES  2	19a. NAME OF RESPONSIBLE PERSON Harold Weinstock
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (include area code) 703-696-8572

Final Report for the DURIP Grant Entitled

***Near-Field Scanning Optical Microscope/ Atomic Force Microscope  
with Broad-band Source for Study of Optical Metamaterials and  
Nanocircuits***

Grant Number FA9550-09-1-0448

Duration: June 1, 2009 till May 31, 2010

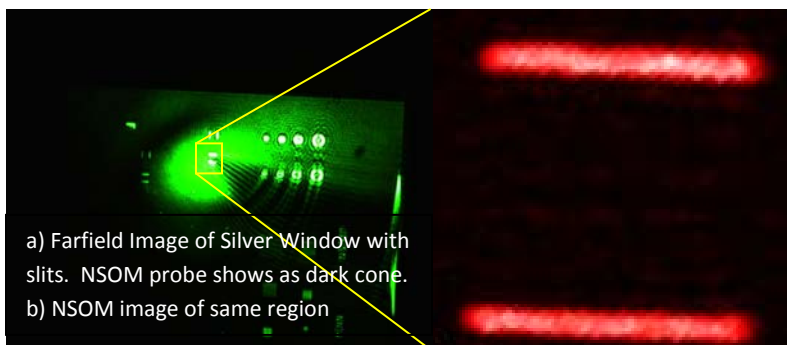
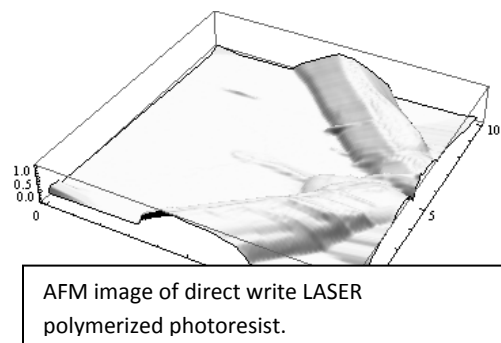
*PI: Nader Engheta  
Co-PI: Marija Drndic  
Postdoc: Brian Edwards  
University of Pennsylvania  
Philadelphia, Pennsylvania 19104*

With the DURIP Grant Number FA9550-09-1-0448 we purchased a Nanonics MV-4000 Near Field Scanning Optical Microscope (NSOM) and a Fianium SC450-6 Super Continuum laser.

Conventional far-field microscopy is limited by the diffraction such that all optical information about features smaller than one-half the wavelength is lost between the sample being investigated and the eye of the observer. This can be likened to the difficulties

inherent in trying to understand the layout of an electronic circuit by examining its radio frequency radiation pattern with an antenna from across the room. However, this does not mean that these features do not affect the fields locally. Just as one can understand the local voltages

with a voltage probe and oscilloscope, using an NSOM, we can understand the local optical fields using a small aperture on the end of an optical fiber and an avalanche photodiode (APD). While this is a useful description of how an NSOM enables near-field microscopy, the analogy is particularly apropos as our goal is to take the powerful modular nature of conventional electronics and move this into the optical domain using through extreme miniaturization and techniques born out of



metamaterials.

Distribution A: Public Release, Unlimited

Additionally, NSOMs are also atomic force microscopes (AFM). Since the near fields decay exponentially away from the sample, it is important to keep the probe at a fixed height above the surface. This is only possible using the feedback inherent in an AFM. This provides an independent image topographic image of the sample.

Devices such as inductors and capacitors take on their most interesting behavior when examined across different frequencies. One significant disadvantage of an NSOM is the optical throughput. For this reason, lasers are often used to provide the intensities required to generate workable optical signals. However, in this case, the monochromatic nature of a conventional laser is decidedly inconvenient for doing broadband characterization of optical devices. In contrast, a super-continuum laser source takes a conventional laser and amplifies it with distortion continuously until it has completely lost its temporal coherency and becomes essentially optical “static”, being broadband and appearing white. However, it remains spatially coherent and can be focused with achromatic optics with the same power as a conventional laser. This laser has on the order of a five milli-Watts of power per nanometer of wavelength. Combining the super-continuum source with a homebuilt monochromator, we can continuously scan the frequency of the optical source while maintaining the same intensity as a conventional laser.

Following one year of ownership of this equipment made possible with the DURIP grant, we have thoroughly evaluated its performance and found it to be perfectly within specifications. We have used the NSOM to map several silver nanowires sent to us by one of our collaborators, and we have also utilized this machine to view the laser focus spot on a substrate in preparation for visualization of the optical field distributions along nanorods. Combined, this equipment yields a system which has enabled us to begin to study the optical nanocircuit elements.

